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Forest Ecological Laboratory, College of Agriculture, Kyoto University, Japan

A 5 year study of pine needle litter decomposition in relation to mass loss and faunal abundances

HIROSHI TAKEDA

With 2 figures

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1. Introduction

In forest ecosystems, litter fall is an important flux of organic matter into the soil-subsystem and the newly fallen litter follows decomposition processes which are governed by biotic and abiotic factors (SWIFT *et al.*, 1979). Many studies have been conducted on the decomposition of leaf and needle litter in various forests (e.g. ANDERSON, 1973; FOGEL & CROMACK, 1977; MACLEAN & WEIN, 1978; TAKEDA *et al.*, 1987). Most of these studies cover only 1–2 year periods in decomposition and long term studies of litter are necessary to follow the decomposition of needles and leaf litter in the mor and moder type forest soils where decomposition is slower than in the mull soils (BERG *et al.*, 1982).

Decomposition studies have demonstrated the changes in mass loss, chemical, microbial and faunal components in the litter. The study of faunal and micro-floral changes during the decomposition of litter is important for the understanding of biological aspects of litter decomposition. Faunal succession during the decomposition of litter has been demonstrated in number of studies (CROSSLEY & HOGLAND, 1962; CURRY, 1969; ANDERSON, 1975). But there are rather few long term studies on faunal succession during the decomposition of litter (METZ & FARRIER, 1967; HÅGVAR & KJØNDAL, 1981; TAKEDA, 1987).

The objectives of the present study are to show the pattern of pine needle decomposition in terms of mass loss, variability of mass loss among the individual litter bags, and faunal abundances over a 5 year period in a pine forest soil with a moder type humus. A further aim was to assess the role of soil fauna in the decomposition processes of pine needle litter.

2. Study area and methods

The study was carried out in a natural forest of Japanese red pine (*Pinus densiflora* SIEB. *et* ZUCC.) mixed with *Chamaecyparis obtusa* ENDLE at Kamigamo Experimental Forest Station of Kyoto University, about 12 km north of the Kyoto city (35.04′ N and 135.43′ E). Details of the study area have been reported in TAKEDA (1976 & 1978). A study plot of 10 m × 20 m in area was laid out in the pine forest and this plot was used for the litter bag study.

Meteorological data were obtained from the station. Mean annual precipitation and evaporation were 1,678 mm and 985 mm respectively. The surface litter layer often dries out in May and mid summer (TAKEDA, 1978).

The soil profile in this study area has a moder type humus with a poorly developed mineral soil horizon (A) which is about 1 cm in thickness. The A_0 layer consists of L, F and H layers ranging from 2 to 5 cm in thickness. The transition between H and A layer is indistinct. The B layer is below 4–5 cm depth. Soil fauna is dominated by micro-arthropods such as Collembola and Acari.

The litter bag method was used to study the decomposition of pine needle litter and faunal succession (CROSSLEY & HOGLAND, 1962). Freshly fallen pine needles were collected in this study plot by 20 litter traps each 25 cm × 25 cm in area during the winter period from December to November 1978. Litter fall was measured in this study plot over a 3 year period from January 1979 to December 1981. Annual litter fall ranged from 4,137 to 4,960 kg × ha^{-1} with a mean of 4,573 kg × ha^{-1} and was concentrated in the winter period from November to January in every year. Among the total litter fall, pine needle litter ranged from 1,790 to 2,160 kg × ha^{-1} with a mean of 2,381 kg × ha^{-1}. Litter fall showed a clear seasonal pattern with a peak in winter period from November to January.

Litter bags measuring 10 cm × 10 cm in are with a mesh size of 1.5 mm were constructed. Three grammes of air-dried pine needles were placed in each litter bag. This litter mass approximated the natural leaf and needle litter fall in this study area. Litter bags were set out in the 10 m × 20 m study plot which was divided into 20 sub-plots each 1 m × 5 m in area. A 1 m × 1 m area was laid out in each sub-plot and 10 litter bags were placed in this area on February 18, 1979. After the removal of the newly fallen litter, the litter bags were fastened to the ground by metal pines to prevent the movement and to ensure good contact between the litter bags and the organic soil layers. Litter bags were collected every 3 months from May 1979 to February 1981. Thereafter litter bags were collected in February in 1981, 1982 and 1983. On each sampling occasion, 10 litter bags were randomly chosen among the 20 sub-plots. After extraction of the soil animals, the needles were air-dried and the mass loss of pine needles was determined. Litter animals were extracted by a modified Tullgren funnel over a 6 d period. Identification, counting and measurements of soil animals were carried out under a binocular microscope.

3. Results

3.1. Changes in mass of litter during the decomposition

Changes in mass of pine needles enclosed in litter bags are shown in fig. 1. The pattern of mass loss was represented by three phases. Decomposition rate in each phase was expressed using the decomposition constant of OLSON (1963) and was $k_1 = 0.054$, $k_2 = 0.024$, and $k_3 = 0.000049$ month-1 for the first, second, and third phase respectively. In the first phase, pine needles showed a rapid mass loss during the 3 months period from February to May and mass loss was 15.5 % of the initial mass. The second phase covered the period from May 1979 to August 1981 and pine needles showed an exponential mass loss ($k_2 = 0.024$ with a correlation coefficient $r = 0.968$). In the third phase, there was no apparent mass loss in the needles in the litter bags.

The variability of mass loss among the individual litter bags represents another aspect of decomposition processes. The variability of mass loss was expressed by the coefficient of variation (C V) as shown by the following formula:

$$CV = (\text{standard deviation})/(\text{mean mass of litter}) \times 100$$

The changes in variability are shown in fig. 1. Variability of mass loss increased with the advance of decomposition processes. The results show a reverse trend between the decomposition rates and variability of mass loss among the samples.

3.2. Faunal abundances during the decomposition

Relative abundances of soil animal groups in the litter bags are shown in table 1. Collembola and Oribatei (Acari) were predominant groups in the litter bag fauna and each accounted for 44 % and 44 % of the total animal abundance respectively. Changes in number of animal groups colonizing the litter bags are shown in fig. 2. Diversity of litter bag fauna peaked in the 15-month litter bags, then was stable throughout the remainder of the study period.

Changes in abundances of the five dominant groups are shown in fig. 2. Total soil animal abundance attained a maximum of 135 individuals per litter bags at 9 months after they were placed in the field and then was stable throughout the rest of the study period. In Collembola, the changes in abundance were similar to those of total fauna. Oribatei showed two peaks in the early (one year) and later decomposition phases. Prostigmata and Mesostigmata mites were later colonizers compared to Collembola and Oribatei. Diptera larvae were abundant in the winters of 1980 and 1982.

3.3. Relationships between the decomposition rates and animal abundances

Soil animals collected in this study consisted of various taxonomic groups. Among them, Collembola, Oribatei and Diptera larvae are predominant in the litter bag fauna and have detritivorous or fungivorous in feeding habits. Data on these groups were calculated on the basis of number of individuals per gramme of pine litter and the changes in numbers during the study period are shown in table 2. Population of decomposer arthropods per gramme of litter increased with the age of litter. To examine the roles of these decomposer arthropods, correlation coefficients were calculated between the decomposition rates and the abundances of decomposer arthropods per gramme. No significant relationships was found between the two variables ($r = 0.232$; n.s.).

Table 1. Relative abundances of soil animals colonizing the litter bags during the study period

Group	Population density [m^{-2}]	Standard errors
1. Collembola	3,141.5	463.4
2. Oribatei	3,073.9	400.8
3. Mesostigmata	263.8	39.5
4. Diptera, larvae	181.2	78.3
5. Prostigmata	175.4	46.6
6. Thysanoptera	113.8	76.4
7. Enchytraidae	67.9	36.2
8. Pseudoscorpionida	16.2	7.3
9. Diplopoda	14.0	9.2
10. Coleoptera	7.6	3.2
11. Chilopoda	3.8	1.4
12. Symphyla	3.1	2.3
13. Araneida	3.0	1.2
14. Formicidae	1.5	1.0
15. Psocoptera	1.5	1.0
16. Lepidoptera, larvae	1.5	1.0
17. Coccoidea	0.8	0.8
18. Isopoda	0.8	0.8
19. Opiliones	0.8	0.8
Total individuals	**7,072.1**	

Table 2. Changes in density of decomposer micro-arthropods during the study period

	Decomposition period				
	1st year	2nd year	3rd year	4th year	5th year
Number of individuals per gramme litter	27.0	36.3	50.8	65.0	40.5

4. Discussion

Decomposition processes of pine needle litter were assessed by the changes in mass loss, variability of mass loss among the individual litter bags, and faunal abundances. There have been some long term studies comparable to the present study period of 5 years. EDMONDS (1984) showed that the decomposition constant of OLSON's **k** decreased with the age of decomposing litter and was stabilized in 2 year in Scot pine litter *(Pinus silvestris)* (BERG *et al.*, 1982) and after 4–5 years in *Pinus radiata* (WILL, 1967), and *Populus* sp. (LOUSIER & PARKINSON, 1976). The reduction in decomposition rates observed in this study were similar to those considered above. The decrease in decomposition rates has been attributed to the chemical properties of litter and BERG *et al.* (1982) and FOGEL & CROMACK (1977) have suggested the importance of lignin fraction as one of the limiting factors in the later decomposition stages of litter.

In contrast to the pattern of mass loss, the variability of mass loss among the individual litter bags increased with the advance of decomposition processes. A similar trend has been demonstrated in ANDERSON (1973) and SEASTEDT *et al.* (1983). SEASTEDT *et al.* (1983) attributed the increasing variability to the accumulated effects of heterogenous micro-habitat conditions for decomposition. In the initial decomposition period, there was a rapid mass loss without a corresponding modification of needle morphology. The initial mass loss has been attributed to the leaching of soluble matter with or without the microbial and faunal agents (NYKVIST, 1959; ANDERSON, 1973; SEASTEDT *et al.*, 1983). The initial mass loss is related to the properties of litter and is rather homogeneous among individual litter bags in different

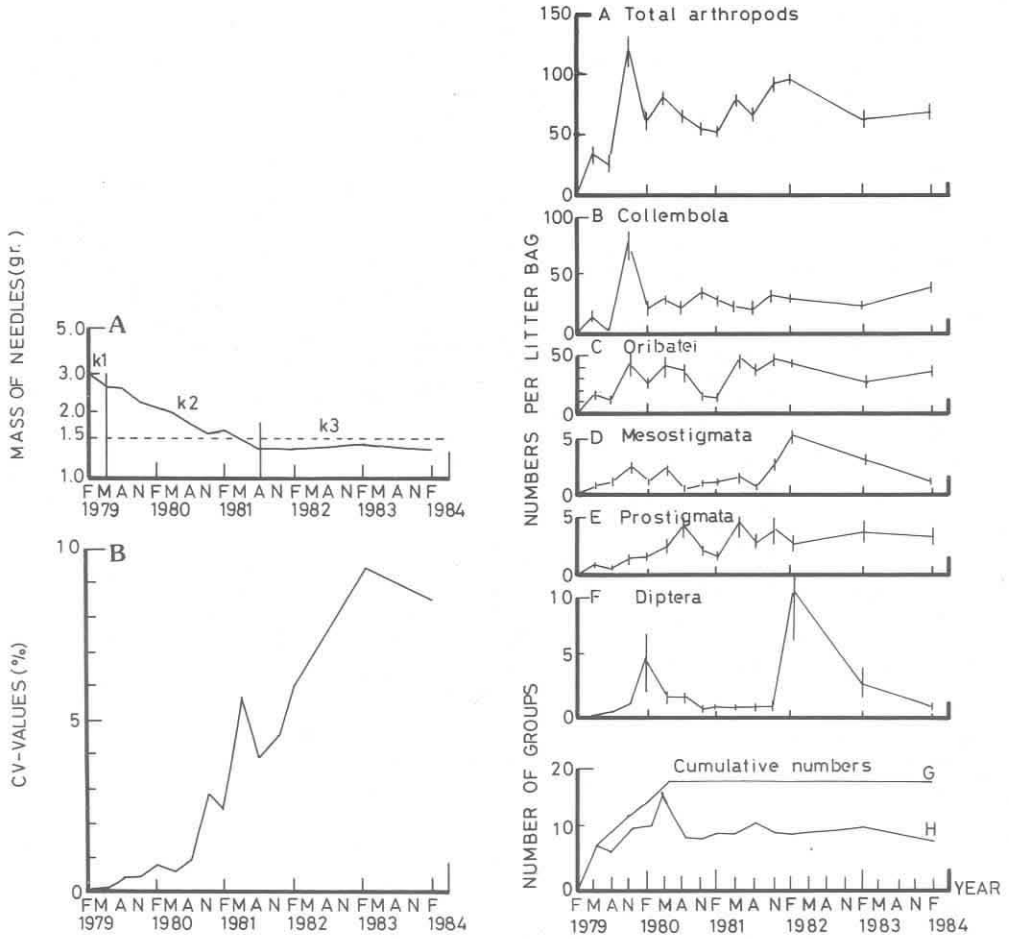

Fig. 1. (A) Changes in mass of pine needles enclosed in the litter bags. Decomposition constant of OLSON's **k** was 0.054, 0.024, and 0.000049 month^{-1} for the initial, middle and later phases respectively. (B) Changes in variability of mass loss among the individual litter bags. The variability of mass loss was expressed by CV.; CV = (standard deviation/mean) × 100.

Fig. 2. Changes in faunal abundances during the study period: (A) Total arthropods, (B) Collembola, (C) Oribatei, (D) Mesostigmata, (E) Prostigmata, (F) Dipterous larvae, (G) cumulative number of animal groups colonized into the litter bags, and (H) number of animal groups colonized into the litter bags. Bars indicate the standard errors.

microhabitats (TAKEDA *et al.*, 1987). The increased variability may represent that of contribution of biotic agents to the decomposition and may provides a useful index for the activities of soil microflora and fauna.

Faunal abundance per gramme of litter increased with the decomposition processes, which supports the view that the activities of decomposers increase with the advance of decomposition. The increase of faunal abundances has been reported by SEASTEDT *et al.* (1983) and HÅGVAR & KJØNDAL (1981) and that of fungal biomass in SWIFT (1973) and BERG & WESSEN (1984). In this study, faunal abundances and decomposition rates were not correlated, suggesting that soil animals do not play a direct role in needle litter decomposition. There was rather a reverse trend between the decomposition rates and faunal abundances and a similar trend was reported in SEASTEDT *et al.* (1983). As decomposition advances, the litter bags move down the soil profile and provide favorable conditions for the colonization of soil animals. The decrease in decomposition rates with

increasing decomposer abundances allows the following explanations for the decomposition process of pine needle litter in the litter bags. Firstly, the contribution of soil animals to needle decomposition is too small to account for the mass loss of litter. In this study plot, the soil fauna mainly consists of micro-arthropods and the macro-fauna are very rare. The role of these micro-arthropods is in the rather indirect regulation of litter decomposition through microfloral and faunal interactions (CROSSLEY, 1977). A second possibility is the shift of feeding of soil animals from the decomposing litter to the recycling organic matter. The recycling of organic matter is a important pathway in the decomposer system (SWIFT *et al.*, 1976). A third factor is a methodological one concerning the litter bag method. This method assumes that the changes in mass of litter bags represent those of the enclosed litter in the litter bags. This assumption is applicable in the case of litter bags place on the surface of litter layer where there is no supply of organic matter from the above layer. Thus in a short term study within a year, the input of organic matter from the upper layers is negligible and the changes in mass of litter bags represent the mass loss of the initial enclosed litter. The litter bags usually move down the soil profile as further litter supply on top of the litter bags and reflect the natural conditions of the decomposition process of litter. In this study, litter bags moved down about 3 cm in depth and were located in the F layer after 5 years. With the advance of decomposition, litter bags move down the soil profile and the changes of mass of litter bags reflect the differences between the input of organic matter from the upper layers and the loss of enclosed litter in the litter bags. The litter bags placed on the litter layer simulate the natural litter and constitute a part of the soil layers. So, as the advance of decomposition, the litter bags move down the soil profile and the observed changes in litter bags represent the decomposition properties of soil layer corresponding to the position of litter bags in the soil profile rather than the loss of enclosed litter.

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TAKEDA, H., 1988. A 5 year study of pine neele litter decomposition in relation to mass loss, and faunal abundances. Pedobiologia **32**, 221–226.

Decomposition of pine needle litter was studied using litter bag method in a pine forest and was followed in terms of absolute mass loss, its variability among individual litter bags, and faunal abundances, over a 5 year period. The pattern of mass loss was represented by three phases; the initial (0 to 3 months), middle (3–30 months) and later (30–60 months) phases respectively; the decomposition rates of the phases were 0.054, 0.024 and 0.000049 month^{-1} using the decomposition constant of OLSON (**k**). Variability in mass loss among the individual litter bags increased with age of the litter. The increasing variability is attributed to the heterogeneity of decomposer activities in microhabitats. Changes in abundances of soil animals were studied over a 5 year period, and Collembola and Oribatei were the predominant decomposers of the pine needles. The number of decomposer animals per gramme of litter increased with the age of litter. A comparison of mass loss and animal abundances suggests that the roles of these animals in litter decomposition processes is indirect. Decomposition processes observed in this study were compared with other similar studies.

Key words: Collembola, decomposition rate, litter bag method, Oribatei mites, pine needle litter, pine forest soil.

Address of the author: Forest Ecological Laboratory, College of Agriculture, Kyoto University, J - 606, Japan.